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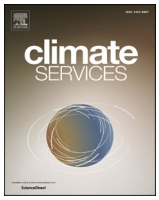

Improving smallholder farmers' access to and utilization of climate information services in sub-Saharan Africa through social networks: A systematic review

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ABSTRACT

The timely availability, access to, and utilisation of actionable climate information services (CIS) serve as an effective mechanism to address the impacts of climate change on smallholder farmers in Sub-Saharan Africa. Scholarly work from diverse contexts reveals that farmers' social networks can be leveraged to promote access to CIS to mitigate climate risk. However, there is no synthesised information on the different insights that comprehensively demonstrate how social networks improve access to and utilisation of CIS among smallholder farmers in Sub-Saharan Africa. This paper employed a systematic literature review methodology to fill this knowledge gap. A stringent inclusion criterion was used to select 32 relevant peer-reviewed papers from an initial pool of 648 for analysis. Our study found farmers' social networks to effectively promote CIS access and utilisation among smallholders in Sub-Saharan Africa. This was mainly as a result of the use of relatable local languages and the opportunity it provided for direct interaction during information flow. Smallholder farmers in big networks with stronger linkages, higher levels of participation, and a greater degree of trust, were identified to be more likely to utilise CIS to improve their livelihoods. Such farmers tend to have higher technical efficiency, productivity, and incomes. To harness social networks to scale up CIS access and utilisation, innovative platforms that can enhance social networking among farmers must be promoted and strengthened by agricultural development stakeholders.

1. Introduction

Despite concerted efforts to keep global warming to well below 2 °C, and pursue efforts to limit the average increase in global temperature to 1.5 °C above the pre-industrial levels, the anthropogenic causes of climate change and its consequent detrimental impacts are still hampering lives and livelihoods (Chapman et al., 2023; Temudo and Cabral, 2023; UNFCCC, 2015; IPCC, 2021; Adzawla et al., 2019). Sub-Saharan Africa (SSA), one of the poorest regions of the human world (Adzawla et al., 2019), and the least contributor to the anthropogenic causes of climate change (Temudo and Cabral, 2023), is the most at risk of its adverse impact (UNFCCC, 2021). Whereas some parts of the region are recording increases in heavy precipitation that often leads to pluvial floods, precipitation declines and aridity trends are on a rising trajectory in most parts of Western, Central and Southern Africa (IPCC, 2021). These are co-occurring with rising trends in hydrological drought resulting in adverse agricultural and ecological impacts in SSA (Chapman et al., 2023). Indigenous knowledge and traditional weather forecasting techniques, which many farmers in SSA rely on for critical farming decisions, are proving increasingly reliable in regions facing growing climate unpredictability (Ebhuoma and Simatele, 2019; Radeny et al., 2019; Nyadzi et al., 2018; Roudier et al., 2014). The fact that most inhabitants of SSA depend on climatic elements for livelihood and survival makes this problem more dire (Adzawla et al., 2019).

In 2012, the World Meteorological Organization (WMO) launched the Global Framework for Climate Services (GFCS) to make climate information available to diverse users to adapt to climate change (Hewitt and Stone, 2021; Hewitt et al., 2012). The strategy was to facilitate the

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production, dissemination, access to, and use of bespoke, timely delivered, credible, cost-effective, user-friendly, and actionable, climate information that was fit-for-purpose and produced in formats that can be integrated into societal decision processes, to the various sectors of the global economy (Vaughan et al., 2016; Hewitt et al., 2012). This was to serve as a decision support tool to equip users, like farmers in SSA, in making decisions regarding the choice of crops and/or variety; the choice of livestock and/or breed; planting time; the timing and magnitude of management activities like irrigation, application of fertilizers, pesticides and insecticides; harvesting, storage, and marketing; and whether to diversify their livelihoods (Ofoegbu and New, 2020). However, recent studies (like Chiputwa et al., 2022; Kosoe and Ahmed, 2022; Chiputwa et al., 2020; Muema et al., 2018) suggest that the use of climate information services (CIS) by farmers in Sub-Saharan Africa (SSA) is relatively low. Kosoe and Ahmed (2022) attributed the limited access to CIS among farmers in SSA to poor mobile and internet connectivity in remote areas, and suggested the use of zero literacy media in expanding access. Also, most farmers are not fully aware of the benefits of using CIS due to low levels of literacy, and those who do have access often lack the technical skills needed for effective use (Kosoe and Ahmed, 2022; Chiputwa et al., 2020). Social networks, the connections among farmers through which goods, services, money, and information flow (Abdul-Rahaman and Abdulai, 2020), are an emerging climate information diffusion and access channel to boost the utilization of climate services among farmers in SSA (Diouf et al., 2019; Rockenbauch and Sakdapolrak, 2017). For instance, once farmers hear of the benefits of CIS use from their peers, their likelihood of use could increase (Owusu et al., 2020). This likelihood could increase further if they see the benefits of using CIS accrue to their neighbors (Mumin et al., 2022).

Although empirical studies (see Mumin and Abdulai, 2022; Ofolsha et al., 2022; Abdul-Rahaman and Abdulai, 2020; Yishay and Mobarak, 2018; Conley & Udry, 2010; Foster & Rosenzweig, 2010) show the importance of social networks in the diffusion and adoption of new agricultural technologies, researchers and policymakers have not fully explored the use of social networks to enhance access and utilisation of climate information services. Most studies that examine CIS access channels do not highlight the role of social networks. Also, the role of farmers' social networks in utilizing climate information services within the local context of SSA has not received adequate attention. The few empirical studies that have addressed the relationship between farmers' social networks and CIS access or use, present isolated evidence (Sprout, 2022; Dadzie et al., 2022; Baffour-Ata et al., 2022; Ofoegbu and New, 2020; Beaman and Dillion, 2018; Diouf et al., 2019). Sprout (2022) synthesized research on the role of social networks in gendered access to climate information services (CIS) among farmers in SSA, underscoring how power dynamics and weaker social networks restrict women's access. However, the analysis was limited to two case studies—Nyantakyi-Frimpong (2019) in Ghana and McKune et al. (2018) in Kenya—both employing social network analysis to identify these barriers. There are currently no studies that comprehensively collate, analyze, and synthesize the insights and empirical findings of the isolated studies to present a holistic picture of how smallholder farmers' social networks promote CIS access and utilization. This paper therefore seeks to unravel an in-depth understanding of the relationship between smallholder farmers' social networks and CIS access and use in SSA from the diverse perspectives of scientific literature. It also seeks to identify gaps in the literature and suggest new directions for future research. Specifically, the systematic review seeks to: (1) investigate how smallholder farmers' social networks have facilitated access to climate information services in SSA; (2) investigate how smallholder farmers' social networks have facilitated the use of climate information services in SSA; and (3) examine how CIS received through farmers' social networks has impacted on the welfare of farming households in SSA.

This paper contributes to the broader discourse of CIS for climate action in SSA. It specifically contributes to knowledge on the effectiveness of social networks in enhancing smallholder farmers' access to CIS and management of climatic information, to reduce vulnerability and risk in the climate-sensitive dependent sector of agriculture.

2. Theoretical perspective

The social network theory (SNT) provides a framework that explains how relationships and interactions among individuals or groups affect information flow and the behavior of decision-making units within a network (Simon et al., 2021; Abid et al., 2017). It acknowledges social structures as networks composed of nodes (actors who are either individuals or groups) and edges (the relationships between them) (Simon et al., 2021; Sprout, 2022; Abid et al., 2017; Morgan, 1986). An individual's position in a network is assumed to be determined by social and economic attributes and these can be leveraged to effectively and efficiently disseminate information within a network (Simon et al., 2021; Borgatti et al., 2018; Abid et al., 2017). This makes SNT particularly useful for understanding how farmers' social connections can serve as effective channels for CIS dissemination in SSA (Sprout, 2022; Simon et al., 2021; Abid et al., 2017). The theory suggests that the strength and structure of social ties influence CIS accessibility. This implies that farmers with stronger, wider networks have better access to critical information, while those with weaker ties face obstacles. A growing body of literature has employed SNT to explore the role of social networks in climate adaptation (Sprout, 2022; Simon et al., 2021; Tesfaye et al., 2020; Dapilah et al., 2019; Abid et al., 2017). For example, Simon et al. (2021) used SNT to show that targeting central actors in rural communities to disseminate weather and market advisory may be a suitable strategy to reach more farmers, including the most isolated. Other studies have used SNT to show how diverse social network participation enhances household resilience to climate change (Dapilah et al., 2019; Abid et al., 2017); to identify key actors in agricultural climate service delivery (Tesfaye et al., 2020); and to propose strategies to improve women's access to CIS through social networks (Sprout, 2022).

3. Methodology

The paper is based on a seven-stage systematic review methodology (Tawfik et al. 2019). The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) reporting guidelines (Pursell and McCrae, 2020) were followed in the presentation of the findings of this review. The first stage of the process involved the definition of research questions, and checking and/or refining the research questions online to ensure that there are no articles that already directly answer these questions and that no other protocol has been registered on the topic of the paper. The second stage of the process involved the identification of the population of literature from which the reviewed articles will be sampled. Based on the research questions, search Terms (Ts) and their Combinations (Cs) were developed (as shown in Table 1). The terms included 'Social Network', 'Farmers' Social Network', 'Climate

Table 1
Terms and combinations for search protocol.

Terms		
T1: Social Networks	T8: Africa	T15: Kenya
T2: Farmers' Social Networks	T9: Sub-Saharan	T16: Nigeria
T3: Access	T10: East Africa	T17: Ethiopia
T4: Climate Services	T11: West Africa	T18: Uganda
T5: Climate Information Services	T12: Central Africa	T19: Rwanda
T6: Climate Information	T13: Southern Africa	T20: Tanzania
T7: Use	T14: Ghana	
Combinations		
C1: (T1 OR T2) AND (T3 OR T7) AND (T4 OR T5 OR T6) AND (T8 OR T9)C2: (T1 OR T2) AND (T3 OR T7) AND (T4 OR T5 OR T6) AND (T10 OR T11 OR T12 OR T13)C3: (T1 OR T2) AND (T3 OR T7) AND (T4 OR T5 OR T6) AND (T14 OR T15 OR T16 OR T17 OR T18 OR T19 OR T20)		

Services', 'Climate Information', 'Climate Information Services', 'Africa', 'Sub-Saharan Africa', and country names within SSA. Various search strings were derived from these terms. Terms of the same group were combined with the Boolean operator 'OR' and those of different groups were combined with the Boolean operator 'AND'.

The string of Ts and Cs were inputted into various search engines; including Web of Science; JSTOR; SCOPUS; Research4Life; Science direct; IEEE Xplore; Springerlink; African Journal Online; Directory of Open Access Journals; CGSpace-CGIAR; and ISI Web of Knowledge. The search was carried out in the English language. Potentially useful publications that were not indexed in the sources mentioned above were searched for in Google Scholar and Google Search Engine. Three different searches (comprising 20 terms and 3 combinations) were carried out on the various online search engines (see Table 1). A total of 648 articles were initially collated. These articles were uploaded and saved in the Zotero reference manager in *ris* format. The data was then exported into Microsoft Excel and duplications were removed.

The third stage defined stringent inclusion criteria to select the relevant articles for the review. The inclusion/exclusion criteria were set within the domain of the review questions and were specified a priori (see Table 2).

Only primary scientific research articles published from 2010 were selected since the global recognition of the need for climate services was formally ratified in 2009 at the World Climate Conference-3, when a Global Framework for Climate Services (GFCS) was universally called (Hewitt and Stone, 2021; Hewitt et al., 2012; WMO, 2009). The 648 articles accessed from the various online databases were screened at three different levels. The first screening was based on the titles, then abstracts and finally using the full-texts. The fourth stage involved selection of the relevant articles for further analysis. The 648 collated articles were reduced to 638 after removal of 10 duplicates (see Fig. 1). At the title screening stage, a total of 377 articles were removed, leaving 261 articles for screening at the abstract level. 74 articles were excluded at the abstract level for being published outside the geographical scope of SSA. An additional 37 articles were excluded at the abstract level for being outside the general domain of agricultural and environmental sciences. A further 118 articles that looked at areas of climate change and climate services unrelated to social networks were excluded at the abstract level (see Fig. 1). A final total of thirty-three (32) articles were used for this systematic review. In the fifth stage, the articles were put under thematic headings. These themes emerged based on the reasons for which the respective studies were conducted. The themes included farmers' social networks and (1) climate information; (2) utilisation of climate information; (3) participation in CIS innovation/adaptation; (4) productivity impact of CIS; (5) livelihood impact of CIS; and (6) food security impact of CIS (see Appendix 1).

The sixth stage involved the synthesis of results and validation evidence (Tawfik et al. 2019). The validity of the sampled articles was demonstrated by how well they fit under three thematic areas that align with our research questions, – Access to CIS, use of CIS and impact assessment. The articles were evenly distributed under each theme – 10 about access to CIS, 11 on utilisation, and 11 on impact assessment. The final stage involved the presentation of the findings of the review. It also presented recommendations for practice and policy-making, and future directions for research to fill existing gaps in knowledge and to strengthen the body of evidence.

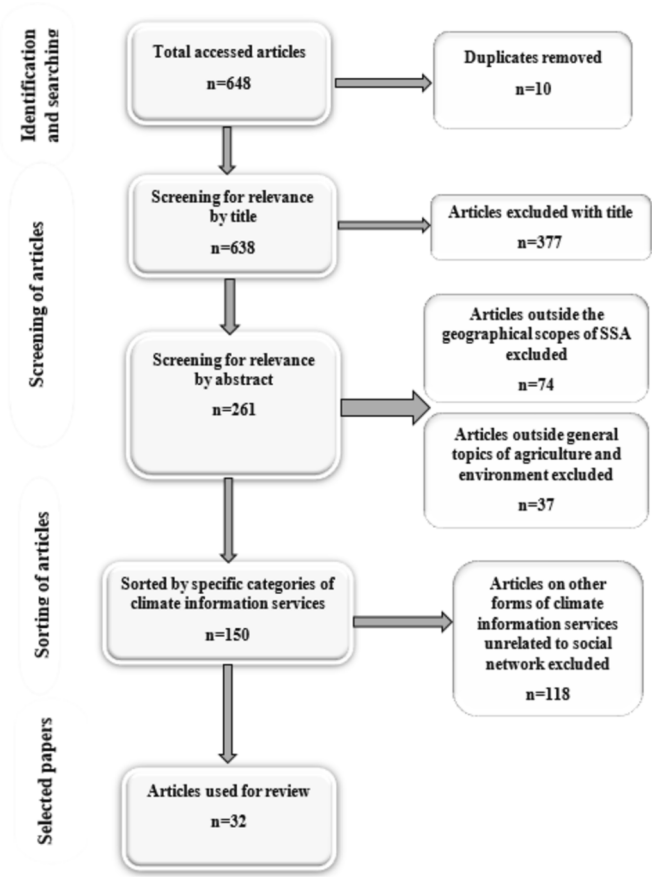

Fig. 1. PRISMA Flowchart for the selection of articles for the systematic review.

4. Results

4.1. Dissemination of climate information services using farmers' social networks in SSA

Farmers' social networks were identified from the 32 selected studies as key channels for disseminating CIS to farmers. Community members (Owusu et al., 2020; Ofoegbu and New, 2020), family and friends (Onyeneke et al., 2023; Gitonga et al., 2020), local authorities such as chiefs and village elders (Onyeneke et al., 2023; Owusu et al., 2020; Ofoegbu and New, 2020; Masinde, 2015), farmer-to-farmer extension (Onyeneke et al., 2023; Dayamba et al., 2018; Etwire et al., 2017), interactive community radio (Chiputwa et al., 2022), non-farmer-based community groups (Onyeneke et al., 2023), and religious organizations (Onyeneke et al., 2023) were the main examples of farmers' social network identified.

The face-to-face communication of climate information in the local language of the farmer through farmers' social networks was found to be a more efficient way to disseminate information than through other media like radio, television, mobile phones and print media (Nkuba et al., 2023; Onyeneke et al., 2023; Etwire et al., 2017). Farmers' social networks, as human-based information sources, have a dialogical aspect which offered an opportunity to ask questions for clarification (Bacci

Table 2
Inclusion criteria for the review.

Inclusion
Primary scientific research articles published from 2010
Studies that have used climate information services and social network concepts fully or partially in sub-Saharan Africa (SSA)
Full articles in the English language
Studies within geographic scope of SSA

et al., 2020). They provide an avenue for feedback, peer support and sharing of experiences that enable farmers to better process the information (Nkuba et al., 2023). Thus, through farmers' social networks, when one farmer gets the information, every farmer gets the information too.

4.2. Types of climate information services accessed by farmers in SSA

Four main CIS were identified from the 32 selected studies. They were weather information, early warning, weather-based market information, and agronomic advice (see Table 3). The identified weather information highlighted various timescales including daily forecasts (Sanfo et al., 2022; Gbangou et al., 2020; Naab et al., 2019; Dayamba et al., 2018), weekly and bi-weekly forecasts (Sanfo et al., 2022; Hirons et al., 2021), 10-day forecast (Chiputwa et al., 2022), and long-term forecasts like monthly (Naab et al., 2019; Etwire et al., 2017), quarterly (Sanfo et al., 2022), seasonal (Chiputwa et al., 2022; Sanfo et al., 2022; Gbangou et al., 2020; Naab et al., 2019) together with multi-year (1–5 years), intra-decadal (5–10 years) and decadal forecasts (Ofoegbu and New, 2020) (Table 3). The identified agronomic advisory services included information on planting time, types of crops to plant, fertilizer type to use, when to apply fertilizer and the variety of seeds to plant (Owusu et al., 2020). Weather and climate data serve as a decision support tool, or can be integrated into such tools, to provide personalized advice to farmers. This can equip them to make data-driven decisions that consider both weather and climate risks, such as improved crop and crop variety selection, optimized planting dates, irrigation scheduling to improve water use efficiency and water productivity, fertilizer application, soil conservation practices that reduce erosion, and pest and disease management. Early warnings are timely alerts and dissemination of information about impending climate-related hazards like storms, droughts, and floods are important emergency preparedness facilities that could enable farmers and farming communities to take mitigating actions to reduce the risks and impacts of these events.

Also, weather-based market information, which is the integration of weather data with market information to help farmers make informed decisions about production, pricing, and supply chain management, can provide early warning signals that can serve as decision support levers for farmers to effectively make better climate-informed decisions regarding what crop to plant, planting dates, how much to produce, when to harvest, timely sales, crop and income diversification, and supply chain management. This will help farmers to navigate climate-related market fluctuations and volatilities. It can also help farmers identify new market opportunities for climate-resilient innovations like improved crop varieties, irrigation, other forms of mechanization, and the likes. Key climate information services like agriculture-based insurance, use of improved varieties, conservation agriculture, precision agriculture, and irrigation advisory services were not identified in the 32 selected articles.

Table 3
Summary of types of CIS access.

Type of CIS accessed	Country	Source
Weather Forecast	Burkina Faso, Ghana, Senegal, Mali	Etwire et al. (2017); Dayamba et al. (2018); Naab et al. (2019); Owusu et al. (2020); Ofoegbu and New (2020); Gbangou et al. (2020); Sanfo et al. (2022), Chiputwa et al. (2022)
Early Warning	Ghana, Senegal, Mali	Dayamba et al. (2018), Owusu et al. (2020); Baffour-Ata et al. (2022);Ngigi and Muange (2022)
Agronomic information	Ghana	McKune et al. (2018); Owusu et al. (2020); Ngigi and Muange (2022); Nkuba, et al. (2023)
Weather-based market information	Ghana	Etwire et al. (2017)

4.3. Farmers' social networks and access to climate information services in SSA

CIS access channels identified in the 32 selected articles included radio (Etwire et al.,2017; Feleke, 2015), TV (Feleke, 2015), agricultural extension agents, print media (published bulletin), mobile phone (text messages and phone calls), and workshop (face-to-face workshops) (see Table 4). Aside from these conventional access channels, farmers' social networks like community members (Mckune et al., 2018; Etwire et al., 2017), family and friends (Gitonga et al., 2020), interactions with local authorities such as chiefs and village elders (Baffour-Ata et al., 2022; Bessah et al. 2021; Gitonga et al., 2020; Mckune et al., 2018; Etwire et al., 2017), interactions with peers or farmer-to-farmer extension (Ofoegbu and New, 2020; Gitonga et al., 2020; Feleke, 2015), and non-farmer-based community groups (Baffour-Ata et al., 2022; Ngigi and Muange, 2022; Diouf et al. 2019) were identified as important CIS access channels in the 32 selected articles (see Table 4). The conventional access channels for CIS like radio, television, and voice call or short message service via mobile phones were reported to be fraught with numerous challenges (Diouf et al., 2019; Muema, et al., 2018; Beaman and Dillion, 2018; Etwire et al., 2017; Feleke, 2015; Cherotich et al., 2012) due to the remote and rural settings of most smallholder farms and farming households in SSA (Baffour-Ata et al., 2022). The unavailability of household information receiving devices like radios, televisions and mobile telephones for receiving climate information (Bessah et al., 2021; Muema, et al., 2018); poor access to stable electricity that makes the operation of electricity-based household information devices difficult (Baffour-Ata et al., 2021; Diouf et al., 2019; Beaman and Dillion, 2018; Muema, et al., 2018; Etwire et al., 2017); and the late delivery of timebound SMS (Etwire et al., 2017; Baffour-Ata et al., 2022) were some challenges that smallholder farmers' social networks offered viable solutions to.

The face-to-face communication of climate information in the local language of the farmer, through farmers' social networks, was reported to be a more efficient way to access information than through the conventional media like radio, television, mobile phones and print media.

Table 4
Summary of key climate information access channels.

Access channel	Country	Source
Social networks	Ethiopia, Ghana, Kenya, Senegal, Namibia,	Feleke (2015), Etwire et al. (2017), McKune et al. (2018), Diouf et al (2019), Gitonga et al. (2020), Ofoegbu and New (2020), Bessah et al. (2021), Ngigi and Muange (2022), Baffour-Ata et al. (2022)
Mobile phone based	Ghana, Kenya, Senegal	Diouf et al (2019), Ofoegbu and New (2020), Ngigi and Muange (2022), Baffour-Ata et al. (2022)
TV	Ethiopia, Ghana, Senegal	Feleke (2015), Diouf et al (2019), Baffour-Ata et al. (2022)
Radio	Ethiopia, Ghana, Kenya, Namibia	Feleke (2015), Etwire et al. (2017), McKune et al. (2018), Diouf et al (2019), Gitonga et al. (2020), Ofoegbu and New (2020), Bessah et al. (2021), Ngigi and Muange (2022), Baffour-Ata et al. (2022)
Print media	Ethiopia, Ghana, Kenya, Namibia	Feleke (2015), Gitonga et al. (2020), Ngigi and Muange (2022), Baffour-Ata et al. (2022)
Extension agent	Ghana, Kenya, Namibia	Etwire et al. (2017), Gitonga et al. (2020), Bessah et al. (2021), Ngigi and Muange (2022), Baffour-Ata et al. (2022)

Social network characteristics like the dialogical attribute which offered an opportunity to ask questions for clarification, and the fact that farmers shared similar values and beliefs were reported to effectively facilitate the communication and assimilation of climate information.

The flow of climate information through farmers' social networks was found to break the language barrier (Cherotich et al., 2012; Beaman and Dillion, 2018) and ensured timely access and timely decision-making (Baffour-Ata et al., 2022) (see Appendix A1). Most of the studies under the 'farmers' social networks and access to climate information' theme (Diouf et al., 2019; Muema, et al., 2018; Feleke, 2015; Cherotich et al., 2012) revealed that farmers' social networks were key facilitators of access to CIS in SSA (Appendix A1). Cherotich et al. (2012) indicated that most farmers preferred to access climate information from peers and community members due to the use of local languages. Feleke (2015) explained that climate information delivered in the English language came with challenges like difficulty in understanding forecast terminologies which reduced the usability of the information and militated against the enhancement of the adaptative capacity of farmers. Using farmers' local dialect in disseminating CIS has proven to be a major advantage for social networks in enhancing access and use. Although government extension services in SSA typically use local languages, their communication can be overly formal or technical. In contrast, social networks rely on trust and personal connections, making communication simpler and more relatable. This familiarity aids in practical understanding and application. Another benefit of social networks relates to time efficiency since members are often nearby or in regular contact, facilitating quick and convenient information exchange. Also, Ofoegbu and New (2020) argued that farmers preferred social network access channels due to the opportunity to ask follow-up questions about the information and make suggestions for improvements. Muema et al. (2018) and Etwire et al. (2017) explained that the interactive nature of the farmers' social networks channels enhanced the uptake and utilization of climate information services in SSA. Beaman and Dillion (2018) posited that higher degrees of participation in social networks increased the efficiency of these access channels. Thus, farmers who actively participated in social networks were found to be more likely to access actionable climate information in a timely manner. To add a gender perspective to this argument, Diouf et al. (2019) reported that female smallholder farmers, especially, benefited from access to climate information through social networks.

4.4. Farmers' use of climate information services and the role of social networks

Farmers' social networks were found to be key facilitators of the utilization of CIS in SSA (see Table 5 & Appendix A2). Most CIS delivered by conventional means are often conveyed in the English language. This creates disinterest and lethargy in most farmers, thereby reducing the use of CIS (Feleke, 2015), since most smallholder farmers in SSA are not educated in the English language (Etwire et al., 2017). Our synthesized results suggest that the use of farmers' social networks breaks the language barrier (Baffour-Ata et al., 2021; Diouf et al., 2019; Etwire et al., 2017; Feleke, 2015), and eliminates constraints of utilization of CIS that come with the poor presentation of CIS (especially weather forecasts) in undecipherable technical formats and poor visual presentations (Baffour-Ata et al., 2021; Diouf et al., 2019; Etwire et al., 2017). Farmers use CIS accessed through farmers' social networks as a decision support tool for various climate-risk mitigating strategies (see Table 5). For instance, decisions on modification of the time of land preparation (Nkuba et al., 2023), planting dates (Owusu et al., 2020; Dayamba et al., 2018; Roudier et al., 2016), as well as selection of crops and their varieties (Roudier et al., 2016; Dayamba et al., 2018) were made by farmers after accessing CIS.

Utilization of CIS was found to be positively influenced by strong social networks in SSA (Nkuba et al., 2023; Dadzie et al., 2022; Ofolsha et al., 2022; Chiputwa et al., 2022; Bazzana et al., 2022; Ngigi and Muange, 2022; Owusu et al., 2020) (see Table 6). Social network attributes such as effectiveness of farmers' social network participation (Diouf et al., 2019); the size of the social network (Ofolsha et al., 2022); and the degree of trust among the interacting parties (Dadzie et al., 2022) were identified to positively influence the utilization of climate information in SSA (see Table 6). Thus, farmers in strong social networks who accessed CIS reported increased use of seasonal forecasts in making decisions relating to the use of improved seed varieties, fertilizers and manure (Chiputwa et al., 2022). They also reported improved adoption of climate change adaptation measures and enhanced market participation (Owusu et al., 2020) (see Table 5 & 6). To highlight the importance of farmers' social networks to the utilization of climate information by women, Ngigi and Muange (2022) indicated that social group participation positively increased their likelihood of adopting climate-smart agricultural practices. This is because social networks can exert informal social pressure that can encourage the use of CIS through peer influence. For instance, a neighbor might demonstrate a solution in person, allowing for immediate and effective action. When one farmer learns something, the whole network does, creating a ripple effect. On the contrary, Bazzana et al. (2022) reported reduced levels of adoption of climate-smart agricultural practices among farmers with poor social network connections (see Table 5 & 6).

These results imply that farmer-to-farmer extension and the interaction of farmers within their social networks hold the key to effective utilization of CIS in SSA. Social networks that engender trust would ensure that recommendations from fellow farmers and local networks are adopted, since they would carry extra weight based on real-life experience. That is, adopting farmers would be almost certain to get similar results as the recommending farmers.

Table 5
Summary of decisions made by farmers after accessing climate information.

Source	Country	CIS received	Decisions made
Roudier et al. (2016)	Niger	Weather forecast	Crop selection, Planting strategy
McKune et al. (2018)	Senegal, Kenya	Weather forecast, Agronomic information	Farm management decisions
Dayamba et al. (2018)	Senegal, Mali	Weather Forecast, Early Warning	Land management, Crop selection, Planting strategy, Farm management decisions
Chiputwa et al. (2022)	Senegal	Weather forecast	Land management, Crop selection, Planting strategy, Farm management decisions, Harvest and post-harvest activities
Gitonga et al. (2020)	Namibia	Weather forecast	Crop selection, Planting strategy, Diversification into other farm activities, Diversification into off-farm activities
Owusu et al. (2020)	Ghana	Weather Forecast, Agronomic information, Early Warning	Crop selection, Planting strategy, Farm management decisions, Diversification into other farm activities, Diversification into off-farm activities
Baffour-Ata et al. (2022)	Ghana	Weather Forecast, Early Warning	Crop selection, Planting strategy, Farm management decisions, Harvest and post-harvest activities
Ngigi and Muange (2022)	Kenya	Weather Forecast, Agronomic information, Early Warning	Crop selection, Planting strategy, Farm management decisions, Diversification into other farm activities
Nkuba, et al. (2023)	Uganda	Weather Forecast, Agronomic information	Land management, Crop selection, Planting strategy, Farm management decisions

Table 6
Characteristic of social networks and the impact of the utilisation of CIS in SSA.

Source	Country	Characteristic of social networks highlighted	How CIS was applied	Impact of CIS
Diouf et al (2019); Owusu et al. (2020); Ofolsha et al. (2022); Chiputwa et al. (2022); Bazzana et al. (2022); Ngigi and Muange (2022); Dadzie et al. (2022); Nkuba et al. (2023)	Senegal, Ghana, Ethiopia, Senegal, Kenya, Uganda	Strength/ Size of networks	Use of improved seed varieties; timely application of inorganic fertilisers and manure; agricultural value chains participation; CSA adoption and climate change adaptation; improved agricultural market performance; adoption of agroforestry, crop rotation and soil conservation practices	Improvement in productivity (especially of women; increase in income; increased awareness of climate risk
Ofolsha et al. (2022); Diouf et al (2019)	Senegal, Ethiopia	Effectiveness of group participation	Use of improved seed varieties, inorganic fertilisers, agricultural value chains participation	Improvement in productivity of women
Dadzie et al. (2022); Mehta and Maretzki (2011)	Tanzania, Ghana	Level of trust in network	Agricultural value chains participation	Increase in income
Roudier et al. (2016); McKune et al. (2018); Naab et al. (2019); Gitonga et al. (2020); Barrett et al. (2020); Mapanje et al. (2020); Djido et al. (2021); Sanfo et al. (2022); Onyeneke et al. (2023)	Niger, Kenya, Senegal, Ghana, Namibia, Zimbabwe, Burkina Faso, Nigeria	Not specified	Adoption of crop rotation and soil conservation practices	Increase in income and expenditures; improvement in technical efficiency and productivity; improved diet,

4.5. Welfare impact of utilization of CIS accessed through farmers' social network

The number of articles that investigated the impact of CIS on the welfare of farmers in SSA was generally low. Only eleven articles, representing 34.4 % of the 32 publications investigated the impact of CIS on the welfare of farmers in SSA. Among these articles, 6 (18.8 %) related to livelihood impact, 1 representing 3 % was on food security impact, while 4 (12.5 %) on agricultural productivity impact. The studies indicated that building trust while expanding "who you know" networks to create social and economic capital in rural African communities is needed for their entrepreneurial initiatives (Mehta, 2011), with a positive impact on livelihood (Roudier et al., 2016) (see Table 6). Also, households that received climate information via farmers' social networks reported marginally higher income levels (Chiputwa et al., 2022; Mapanje et al., 2020; Barrett et al., 2020; Roudier et al., 2016), higher food expenditure, and more diversified diets (Gitonga et al., 2020; McKune et al., 2018) (Table 6).

For instance, McKune et al. (2018) investigated how interventions to improve climate information services led to greater food security. Various social network channels are highlighted as being the means of access to CIS. McKune et al. (2018) reported that areas with historically higher levels of CCAFS-CIS interventions are implementing CSA at higher rates and also are experiencing more food security (see Table A5 of Appendix 1). Gitonga et al. (2020) employed propensity score matching, with a sensitivity analysis for hidden bias, to evaluate the impact of climate information on adaptive capacity and food security. It iterated the point that working with local leaders and integrating climate information into local knowledge systems can enhance access and utilization in farm decisions. Gitonga et al. (2020) reported that households that received this climate information had more diversified diets, higher food expenditure and engaged in more climate change adaptive strategies. Also, Roudier et al. (2016), in assessing the benefits of weather and seasonal forecasts for millet growers in Niger, found that 10-day forecasts alone or a combination of 10-days and seasonal forecasts could increase income by 1.8 % to 13 % according to adaptation possibilities (see Table A5 of Appendix 1). It was also found that the use of climate services improved technical efficiency (Djido et al., 2021), and the productivity of land, labor (Sanfo et al., 2022) and crops (Djido et al., 2021), with a positive impact on agricultural growth (Onyeneke et al., 2023; Naab et al., 2019) (Table 6). Effective participation in larger social networks contributed to productivity improvement for female smallholder farmers in Senegal (Diouf et al., 2019) and Kenya (Ngigi and Muange, 2022).

5. Discussion

Our results reveal that the bundle of climate information services accessed by farmers in SSA is limited in regard to the integration of market information. Climate information services in SSA have traditionally focused on weather information. However, climate risk management is a polycentric task that requires a comprehensive and coordinated approach to deliver multidisciplinary solutions. Market information, when integrated into climate information services, can enhance farmers' adaptive capacity to climate change by helping farmers manage both production and market risks emanating from the adverse effect of climate change. Also, our systematic review has provided new insights into how effective social networks can enhance access to and utilization of CIS for improved welfare among smallholder farmers. Our synthesis has shown that the use of farmers' social networks has the potential to eliminate the existing constraints of access and utilization of CIS. Due to the dialogical aspect of farmers' social networks as an access channel, the farmers are able to process information experimentally and hence are able to learn new ways of application and replication. Being able to discuss with other farmers and experts together with farmers' own observations creates a toolbox of knowledge and skills for farmers to cope with the changes in climate. Social networks with other farmers also create a possibility for peer support and to share experiences. The regular availability of the farmers' peers, friends, relatives, neighbors ensured continuous understanding and communication of the information.

The literature suggests that women with weaker social ties face challenges in obtaining CIS (Sprout, 2022). For instance, Nyantakyi-

Frimpong (2019) found household power dynamics in Northern Ghana to create gender-specific barriers to CIS access, limiting women's ability to receive information. Men, who typically had firsthand access to CIS, often did not pass it on to female relatives. Also, seniority in polygamous households and religious status were found to further affect information flow, with junior wives being the least likely to access CIS through family networks. The literature also highlights that social networks can significantly enhance CIS access for women. McKune et al. (2018) identified social networks like churches, women's groups, and table-banking associations as important channels for accessing CIS, particularly for women in Kenya. They highlighted that building strong connections between the least and most empowered women can strengthen community-based learning and knowledge-sharing. According to McKune et al. (2018), the gender gap in CIS access was linked to a lack of emphasis on social networks as effective dissemination channels by service providers. Diouf et al. (2019) also noted that female smallholder farmers benefited significantly from accessing climate information through these networks. Ngigi and Muange (2022) further demonstrated that women's involvement in social groups greatly boosted the adoption of agroforestry, crop rotation, and soil conservation practices. In both Senegal and Kenya, broader social network participation was associated with increased productivity among female smallholders (Diouf et al., 2019; Ngigi & Muange, 2022).

Our systematic review has also brought to the fore the low number of CIS studies that investigated the impact of climate services in general, and the use of social networks in particular, on the welfare of farmers in SSA. This low number of studies on the impact of climate information services on the welfare of farmers may be attributed to the difficulties in conducting an impact assessment of climate information services. A major cause of this challenge is the lack of counterfactual evidence in climate information projects, which arises due to the non-exclusive and indivisible nature of most climate information. Thus, any attempt to identify and demarcate a control group as a quasi-counterfactual would be subject to spill-over effects or the problem of contamination.

6. Conclusion and future research

The dissemination, access to, and effective use of climate information services (CIS) in a timely manner are essential tools for helping smallholder farmers cope with the effects of climate change. Isolated evidence across various contexts highlights the potential of farmers' social networks in enhancing access to, and use of CIS, in order to effectively manage climate-related risks. However, there is a lack of comprehensive synthesis of these insights to clearly present a holistic picture. This paper utilized a systematic literature review methodology to analyze and consolidate existing knowledge on how social networks enhance access to, and use of CIS among smallholder farmers in Sub-Saharan Africa. Four main CIS are typically accessed in SSA – weather information, market information, agronomic information and early warnings. Climate information services such as agriculture-based insurance, conservation agriculture, precision agriculture, and irrigation advisory services were not discussed in the literature. Future research could explore ways to integrate these services into the delivery of CIS in SSA. The face-to-face communication through the farmer's local dialect, and the dialogical attribute which offered an opportunity to ask questions for clarification makes farmers' social networks a more efficient way to disseminate and access CIS in SSA. The efficiency of farmers' social networks as CIS access channels increases with higher degree of group participation. Thus, farmers who actively participate in social networking are more likely to access actionable climate information in a timely manner.

Farmers' social networks are also key facilitators of CIS use among farmers in SSA. The strength and effectiveness of farmers' social network participation, the size of the social network, and the degree of trust among the interacting parties are important attributes of farmers' social networks that facilitate the utilization of CIS. Women, particularly, are more likely to access and use CIS when they actively participate in social groups. Households receiving climate information have marginally higher income levels, higher food expenditure, and more diversified diets. Also, the use of climate services increases technical efficiency and agricultural productivity in SSA. There is an urgent need to facilitate the formation of gender-sensitive farmer-based organizations (FBOs) to facilitate the access to, and use of climate information. Local opinion leaders and other stakeholders, including non-governmental and research-for-development organizations, should collaborate with other stakeholders in the private sector to develop gender-sensitive innovative platforms that can enhance social networking among farmers in their catchment areas. Internet and intranet/offline based social networking platforms for farmers to interact and share knowledge is suggested. Future research could use rigorous methodologies like randomized controlled experiments with a strictly defined control group, since existing studies use only participants or beneficiaries of CIS projects for assessment to draw conclusions.

CRediT authorship contribution statement

Collins E. Appiah: Conceptualisation, analysis, writing, editing, & review. **William Quarmine:** Writing – review & editing, Validation, Supervision. **Charity Osei-Amponsah:** Writing – review & editing, Validation, Supervision. **Andrew E. Okem:** Writing – review & editing, Validation, Supervision. **Daniel B. Sarpong:** Review, Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 1:. Summary of publications under the various research themes

Table A1. Summary of publications under the farmers' social network and access to climate information theme.

Year	Author(s)	Title	Publication	Contribution
2012	Cherotich, V.K., Saidu, O. & Bebe, B.O.	Access to climate change information and support services by the vulnerable groups in semi-arid Kenya for adaptive capacity development	African Crop Science Journal, 20 (2), 169 – 180	Most respondents preferred the use of indigenous knowledge to access climate information due to the use of local language
2015	Feleke, H.G.	Assessing Weather Forecasting Needs of Smallholder Farmers for Climate Change Adaptation in the Central Rift Valley of Ethiopia	Earth Sci Clim Change 2015, 6(10), 1–13 https://doi.org/10.4172/2157–7617.1000312	Adaptation capacity of farmers in using weather information are constrained by language problems, difficulty in understanding forecast terminology, and inconsistency in the time of information provision
2017	Etwire, P.M, Buah, S., Ouédraogo, M., Zougmoré, R., Partey, S.T., Martey, E., et al.	An assessment of mobile phone-based dissemination of weather and market information in the Upper West Region of Ghana	Agric & Food Security, 6(8), 1–13	Farmer-to-farmer extension services significantly influences farmers' decision to patronize mobile phone-based weather and market information. Compared with AEA contact, farmer-to-farmer extension has a larger effect on the probability of patronizing mobile phone-based weather and market information.
2018	Beaman and Dillion	Diffusion of agricultural information within social networks: Evidence on gender inequalities from Mali	Journal of Development Economics 133 (2018), 147–161	Information diffusion declines with social distance
2018	Muema, E., Mburu, J., Coulibaly, J. & Mutune, J.	Determinants of access and utilisation of seasonal climate information services among smallholder farmers in Makueni County, Kenya	Heliyon 4 (2018) e00889	Participation in farmers' groups increased farmers' access and use of CIS
2019	Diouf et al.	Factors influencing gendered access to climate information services for farming in Senegal	Gender, Technology and Development, 1–18. DOI: https://doi.org/10.1080/09718524.2019.1649790	Membership in a community organization has a positive impact on women's access to climate information .
2020	Ofoegbu and New	The role of farmers and organizational networks in climate information communication: the case of Ghana	International Journal of Climate Change Strategies and Management	Information flow and exchange through organizational collaboration network is having limited effect on improving farmers' knowledge about climate risks, impacts and available risk response options because feedback flow of information from farmers to national level organizations has not been effective in addressing localized climate/agro challenges
2021	Bessah, E, Donkor, E., Raji, O.A., Taiwo, O.J. et al.	Determinants of Maize Farmers' Access to Climate Information Services in Ghana	Book chapter In W. Leal Filho et al. (eds.), Handbook of Climate Change Management	Maize farmers' decision to access climate information is influenced by a set of factors related to socioeconomic characteristics, institutional characteristics, community infrastructure, and awareness of climate change
2022	Baffour-Ata, F., Antwi-Agyei, P., Nkiaka, E., DougilL, A., et al.	Climate Information Services Available to Farming Households in Northern Region, Ghana	Weather, climate, and society, 14, 467–479	Timely and reliable access to climate information services is enhancing farmers' decision-making capacities

Table A2. Summary of publications under the farmers' social network and utilisation of climate information theme.

Year	Author(s)	Title	Publication	Contribution
2018	Dayamba, D.S., Ky-Dembele, C., Bayala, J., et al.	Assessment of the use of Participatory Integrated Climate Services for Agriculture (PICSA) approach by farmers to manage climate risk in Mali and Senegal	Climate Services 12 (2018) 27–35	In Senegal and Mali, respectively 97 % and 76 % of the respondents found the approach 'very useful'. The approach enabled farmers to make strategic plans long before the season, based on their improved knowledge of local climate features. PICSA stimulated farmers to consider and then implement a range of innovations
2020	Gbangou et al.	Coproducing Weather Forecast Information with and for Smallholder Farmers in Ghana: Evaluation and Design Principles	Atmosphere 2020, 11, 902	Application of modern technology in a coproduction process with targeted training and monitoring can improve smallholder farmers' access to and use of weather and climate forecast information
2022	Chiputwa et al.	Transforming climate science into usable services: The effectiveness of co-production in promoting uptake of climate information by smallholder farmers in Senegal	Climate Services 20 (2020) 100,203	Increases farmer's awareness of WCI by 18 %, access by 12 % and uptake by 10 %. Furthermore, use of seasonal forecasts is generally associated with a higher proportion of farmers using improved seed, fertilizers and manure, but negatively with crop diversification
2023	Nkuba, M.R., Chanda, R., Mmopelwa, G., Kato, E., Mangheni, M.N., Lesolle, D., Adedoyin, A., & Mujuni, G.	Factors associated with farmers' use of indigenous and scientific climate forecasts in Rwenzori region, Western Uganda	Regional Environmental Change (2023) 23(4),1-14. https://doi.org/10.1007/s10113-022–01994-0	One of the significant factors associated with using both IFs and SFs was farmer-to-farmer network

Table A3. Summary of publications under the farmers' social network and participation in innovation theme.

Year	Author(s)	Title	Publication	Contribution
2020	Owusu et al.	Does the use of climate information contribute to climate change adaptation? Evidence from Ghana	Climate and Development	Use of CIS is positively influence by strong social network. Household heads' decision to adopt a climate change adaptation measure is positively and significantly affected by membership in the farmer-based organization
2021 (b)	Djido, A., Zougmore, R.B., Houessionon, P., Ouedraogo, M., et al.	To what extent do weather and climate information services drive the adoption of climate-smart agriculture practices in Ghana?	Climate Risk Management 32 (2021) 100,309	The use of WCIS significantly increases the adoption of water management and multiple cropping practices
2022	Bazzana, D., Foltz, J., & Zhang, Y.	Impact of climate smart agriculture on food security: An agent-based analysis	Food Policy 111 (2022) 102,304	The community relationship positively affects the CSA adoption. Farmers with poor connections to food markets benefit less from CSA due to stronger price oscillations
2022	Ngigi, M.W., & Muange, E.N.	Access to climate information services and climate-smart agriculture in Kenya: a gender-based analysis	Climatic Change (2022) 174:21	Membership in a mixed-gender group positively affected adopting agroforestry and crop types for wives, as well as crop rotation and soil conservation practices.
2022	Ofolsha, D.M., Kenee, F.B., Bimirew, D.A., et al.	The Effect of Social Networks on Smallholder Farmers' Decision to Join Farmer-Base Seed Producer Cooperatives (FBSc): The Case of Hararghe, Oromia, Ethiopia	Sustainability 2022, 14, 5838	The size of social network, linkage with relatives and extension agents influence farmers' decision to join farmer-base seed producer cooperatives
2022	Dadzie, S.K.N., Ndebugri, J., Inkoom, E.W., & Akuamoah-Boateng, S.	Social networking and risk attitudes nexus: implication for technology adoption among smallholder cassava farmers in Ghana	Agriculture & Food Security 11(41), 1–24	The effectiveness and usefulness of social interactions as well as a high degree of trust by cassava farmers in their social networks have higher tendencies to lower the degree of risk aversion behaviour of the farmers to significantly influence technologies adoption decisions positively
2022	Mumin, Y.A., Abdulai, A., & Goetz, R.	The role of social networks in the adoption of competing new technologies in Ghana	J Agric Econ. 2022;1–24	Adoption decisions in a network tend to converge on one variety. Significance of neighbourhood effects in the adoption of competing technologies

Table A4. Summary of publications under the productivity impact of CIS theme.

Year	Author(s)	Title	Publication	Contribution
2019	Naab et al.	The role of climate services in agricultural productivity in Ghana: The perspectives of farmers and institutions	Climate Services 13 (2019) 24–32	All respondents attest to the fact that CS is indeed important for agricultural growth in the advent of the impacts of climate change
2021 (a)	Djido, A., Houessionon, P., Nikoi, G., Ouédraogo, I., Ouédraogo, M., et al.	The impacts of weather and climate information services on technical efficiency and farm productivity among smallholder farmers in the Upper West Region of Ghana	CCAFS Working Paper no. 392	Use of CIS increased technical efficiency by 6 %, and sorghum yield by 35 % corresponding to 150 Kg/Ha increased productivity
2022	Sanfo, S., Salack, S., Saley, I.A., Daku, E.K., et al	Effects of customized climate services on land and labor productivity in Burkina Faso and Ghana	Climate Services 25 (2022) 100,280	Land productivity increased by 200 % and labor productivity doubled. CCS was particularly favorable to land and labor productivity of farmers who were committed to the advisory given by the CCS providers
2023	Onyeneke, J.C., Umeh, G. N., & Onyeneke, R.U.	Impact of Climate Information Services on Crop Yield in Ebonyi State, Nigeria	Climate 2023, 11 (7), 1–16. https://doi.org/10.3390/cli11010007	The use of CIS in planning for farming activities significantly increased rice, maize, and cassava yields

Table A5. Summary of publications under the food security impact of CIS theme.

Year	Author(s)	Title	Publication	Contribution
2018	McKune, S., Poulsen, L., Russo, S., Devereux, T., & et al.	Reaching the end goal: Do interventions to improve climate information services lead to greater food security?	Climate Risk Management 22 (2018) 22–41	No direct correlation between receipt of CIS and use of CSA practices was found, nor was a relationship established between use of CSAs and food security. Uncovered that areas with historically higher levels of CCAFS-CIS interventions are implementing CSA at higher rates and also are experiencing more food security

Table A6. Summary of publications under the livelihood impact of CIS theme.

Year	Author(s)	Title	Publication	Contribution
2011	Mehta, K., Semali, L., & Maretzki, A.	The primacy of trust in the social networks and livelihoods of women agro-entrepreneurs in northern Tanzania	African Journal of Food, Agriculture, Nutrition and Development 11(47), 1–13	Building trust while expanding "who you know" networks to create social and economic capital in rural African communities needed for their entrepreneurial initiatives
2016	Roudier, P., Alhassane, A., Baron, C., Louvet, S., & Sultan, B.	Assessing the benefits of weather and seasonal forecasts to millet growers in Niger		10-days forecasts alone or a combination of 10-days and seasonal forecasts could increase income by 1.8 % to 13 % according to adaptation possibilities
2020	Gitonga, Z.M., Visser, M., & Mulwa, C.	Can climate information salvage livelihoods in arid and semiarid lands? An evaluation of access, use and impact in Namibia	World Development Perspectives 20 (2020) 100,239	Households receiving climate information had more diversified diets, higher food expenditure and engaged in more adaptive strategies
2020	Barrett, S., Ndegwa, W., & Maggio, G.	The value of local climate and weather information: an economic valuation of the decentralised meteorological provision in Kenya	Climate and Development, 1–16. https://doi.org/10.1080/17565529.2020.1745739	Households receiving KMD's local advisories and seasonal forecasts have marginally higher income levels
2020	Mapanje et al.	The impact of climate information services on smallholder farmers' livelihood outcomes	African Journal of Rural Development, Vol. 5 (2), 29–47	Access to tailored climate information services had a positive and significant effect on farmers' incomes.

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Year	Author(s)	Title	Publication	Contribution
2022	Chiputwa et al.	Co-production, uptake of weather and climate services, and welfare impacts on farmers in Senegal: A panel data approach	Agricultural Systems 195 (2022) 103309	Uptake of weather and climate information increases crop income by between 10 and 25 %

Data availability

No data was used for the research described in the article.

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